I-880 Field Experiment
Analysis of Incident Data

ALEXANDER SKABARDONIS, KARL F. PETTY, ROBERT L. BERTINI, PRAVIN P. VARAIYA, HISHAM NOEIMI, AND DANIEL RYDZEWSKI

The I-880 field experiment has produced one of the largest data bases on incidents and freeway traffic-flow characteristics ever compiled. Field data on incidents were collected through observations of probe-vehicle drivers before and after the implementation of freeway service patrols (FSPs) over a freeway section. Supplementary information was collected from the California Highway Patrol's computer-aided dispatch system, FSPs, and tow-truck company logs. The incident patterns are described and the major factors affecting incident frequency and duration are identified. FSPs significantly reduced the response times but did not have a significant effect on the duration of all incidents.

Incidents are accidents, vehicle breakdowns, spilled loads, or any other random events that reduce the capacity of the road and cause congestion if the traffic demand exceeds the reduced capacity at the incident location. The impact of incidents on traffic flow depends on incident frequency, location, type, severity, and duration; the traffic demand and capacity at the facility; and the availability of incident management programs. The most frequently cited FHWA study (*1*) reports that incidents account for 61 percent of all congestion delay in the United States. The California Department of Transportation (Caltrans) also estimates that 50 percent of motorist delays on freeways are incident-related (*2*). Furthermore, incidents may cause accidents because of the stop-and-go traffic conditions and the hazards of vehicles and pedestrians stalled in the roadway.

In response to the growing adverse effects of incidents on travel conditions, incident management programs have been initiated in several metropolitan areas. Incident management programs include freeway surveillance systems, incident response teams, law enforcement officers, motorist assistance patrols, and other means to detect, respond to, and clear incidents (*3*). The goal of such programs is to restore the freeway to full capacity after the incident occurs and to provide information to motorists. Any reduction in detection, response, and clearance times reduces the total incident duration, which in turn reduces the congestion delay.

The design and evaluation of incident management programs should be based on field data on incident characteristics. However, field data on incident characteristics and their effects on traffic flow so far have been limited; most studies were conducted in the 1960s and 1970s, when urban freeways were less congested and driver and vehicle characteristics were quite different. For example, the original source of the most frequently quoted incident rate of 124 incidents per million vehicle-km (200 incidents per million vehicle-mi) (*4,1*) is the limited data conducted in 1958 on five Interstate segments in upstate New York with annual average daily traffic (AADT) of 10,000 vehicles per day (vpd) (*5,6*). Recent studies on freeway incident patterns in Los Angeles (*7,8*) and Seattle (*9*) focused on accidents using accident records (e.g., California's TASAS system, police reports, and patrol logs) as data sources. Although previous studies provided valuable sources of information, none of these studies did a comprehensive field data collection and analysis to determine incident patterns and their effects on the freeway traffic flow.

This paper presents the findings from the analysis of incident data collected as part of the I-880 field experiment. The I-880 study was conducted to evaluate the effectiveness of the freeway service patrols (FSPs) implemented at a particular freeway section (*10*). Field data on incidents were recorded, probe-vehicle runs were performed, and speed-flow-occupancy data were collected from closely spaced loop detectors. The collection and processing of the field data have produced the largest and most comprehensive data base on freeway operations compiled to date. This fully computerized data base and data analysis software are available on the Internet and are used by researchers worldwide (*11*).

This paper is organized as follows. First, the incident data collection and processing and the development of the data base are described. Next, the results relating to incident frequency and characteristics are discussed. The analyses of incident response, clearance, and durations are discussed in the next section along with the effects of FSPs on incident durations. Finally, the comparison of incidents from the data sources is reported.

INCIDENT DATA BASE

The primary source of information on incidents was the field observations by the probe-vehicle drivers traveling the freeway section at an average headway of 7 min. Additional data on incidents in the study area were collected from the California Highway Patrol (CHP) computer-aided dispatch (CAD) system and officers' records, tow-truck company logs, and FSP records. The sources and use of those data are briefly described in the following section.

Field Observations

Field data were collected before and after the implementation of an FSP on a 14.8-km (9.2-mi) section along the I-880 freeway located in the city of Hayward, Alameda County, California. The selected test site has one of the highest frequencies of accidents and other incidents in the San Francisco Bay Area. The geometry of the section varies

A. Skabardonis, K. F. Petty, R. L. Bertini, and P. P. Varaiya, Institute of Transportation Studies, University of California, Berkeley, Calif., 94720-1720. H. Noeimi, JRH Transportation Engineering, Inc., 1580 Valley River Road, Suite 160, Eugene, Oreg. 97401. D. Rydzewski, URS Consultants, Inc., 1506 Virginia Beach Road, Virginia Beach, Va. 23462.

from three to five lanes, includes a high-occupancy-vehicle (HOV) lane, and lacks shoulders in several segments. The AADT ranges from 160,000 to 200,000 vpd. Loop detectors are located as pairs at approximately 0.54-km (0.33-mi) intervals on each freeway lane and the ramps.

The field data were collected for 6 hours a day during the peak periods (6:30–9:30 a.m. and 3:30–6:30 p.m.). The before study was conducted for 24 weekdays in the spring of 1993, and the after study took place in the fall for 22 weekdays. The periods for data collection were selected on the basis of historical data on accidents and traffic-volume patterns at the site to minimize seasonal variations in the incident and traffic patterns.

Using two-way radios, the probe-vehicle drivers reported every incident they witnessed as they traveled along the study section, along with the incident's characteristics, as follows:

- Type (e.g., accident, breakdown, debris),
- Severity (number of lanes affected),
- Description of the vehicles involved (type, color),
- Location (direction, lane, upstream or downstream from the nearest exit),
- Time the incident was first witnessed, and
- Updates (e.g., presence of CHP or tow truck).

The data were recorded by the study supervisor on an incident data-collection form and then input to a computerized data base for further analysis.

A total of 2,181 incidents—1,210 in the before study and 971 in the after study—was observed by the probe vehicle drivers during the ninety-two 3-hr data-collection periods. Approximately 26 percent of those observations involved CHP ticketing-related events, that is, incidents other than accidents and breakdowns involving the presence of a CHP officer. According to the information from CHP officers' logs, most of these incidents were citations for violations of the HOV lane usage in the study area. Although these incidents may have some effect on traffic flow, it is unlikely that they would be affected by any incident management measure, and they were excluded from further analysis.

CHP/CAD System

The Bay Area's CHP/CAD center receives calls about incidents on freeways from various sources including CHP officers, motorists using cellular phones, call boxes, other public agencies, and FSP drivers. The information is recorded on computerized incident logs. These logs include the call source and time, incident type and severity (e.g., accident, breakdown, number of lanes affected), description of the vehicles involved (type, license plate number), location (direction, lane, upstream or downstream from the nearest exit), and response and clearance times (CHP, FSP if any, tow-truck call, arrival and departure).

A total of 218 incidents were reported in the before study and 283 incidents in the after study. About 33 percent of the reported incidents were accidents and 56 percent were breakdowns. The remaining 11 percent were classified as debris and other. The 30 percent increase in the number of reported incidents in the after study is almost entirely attributable to the reports made by the FSP trucks. Also, the FSP implementation eliminated the need for CHP officers to stop at every incident. In fact, after FSP implementation, there was a reduction in the number of breakdowns attended by CHP (from 77 percent of total breakdowns before to 49 percent after), and a 21 percent reduction in the average time spent by CHP per breakdown.

FSP and Tow-Truck Company Logs

Private tow-truck companies such as the American Automobile Association were providing service to stranded motorists during the before study and when requested during the after study. The tow-truck operators were contacted by CHP and asked to provide the following information on motorist assists during the periods of the field study experiment: times of tow-truck call, dispatch, arrival and departure, incident location, vehicle type, type of assist, and towing location (if any). The data were used to verify the accuracy of the field observations, especially the long response times observed for several incidents in the before study. The logs showed that tow trucks were called as much as 2 hr after the incident was first observed. This probably is because the drivers abandoned their vehicles and called for assistance at a later, more convenient time.

The FSP tow-truck drivers fill out an assist form each time they provide service to a motorist. These forms include information on type and location of the incident, type of assistance provided, and arrival and departure times of the FSP unit. A total of 356 incidents were recorded by FSP drivers in the after study. Most of the assists involved vehicles with mechanical or electrical problems. Vehicles with flat tires and vehicles that had run out of gasoline accounted for about 24 percent of the assisted incidents, and 18 percent of the incidents involved abandoned vehicles. Thirty-four percent of the total disablements led to towing by FSP trucks. The average clearance time for the disablements that did not require towing was 12 min, and the average clearance time for incidents that had to be towed off the freeway was 28.6 min (including the time that the tow truck becomes available for service.) The FSP logs did not provide detailed information for accidents other than that the FSP assisted in removing involved vehicles from travel lanes.

ANALYSIS OF FIELD DATA

Incident Frequency and Characteristics

Table 1 shows the classification of incidents based on type and place of occurrence. Most of the incidents were breakdowns on the right shoulder. The breakdown causes included stalls due to mechanical or electrical problems; flat tires; and running out of gas. This category also includes abandoned vehicles and all other stops (e.g., to check

TABLE 1 Incident Classification

	LOCATION				
INCIDENT TYPE	Median	In-Lane	Rt. Shoulder	TOTAL	%
Accident	29	35	103	167	10.3
Breakdown	60	24	1347	1431	88.6
Debris/Pedestrian	1	15	2	18	1.1
Total	90	74	1452	1616	

maps). The estimated incident rate on the study section was 64.6 incidents per million vehicle-km (104 incidents per million vehicle-mi) of travel, about half of previously reported rates (*1*,*4*).

The number of in-lane incidents depends on the presence of shoulders, incident type, type of vehicles involved, and the data-collection methodology. The proportion of the in-lane incidents was 4.7 percent (Table 1), which translates into 0.0032 lane-blocking incidents/hr/lane-km (0.0051 lane-blocking incidents/hr/lane-mi). Higher rates have been reported in other studies (*12*). However, it is plausible that more incidents occurred on the main line and were quickly moved to the shoulder before they were observed by the probe-vehicle drivers. It is likely that a higher number of in-lane incidents would have been observed if other means (e.g., closed-circuit television) had been used for data collection.

Figure 1 depicts the incident tree that summarizes the overall incident patterns in the study area (excluding debris and pedestrian incidents). Also presented are values reported by FHWA (*1*) on the basis of studies conducted in the 1970s. The proportion of in-lane incidents and accidents is very close to the previously reported data. The I-880 section, however, has a much higher proportion of in-lane accidents (59 percent of all incidents in travel lanes are accidents, as opposed to 21.3 percent reported in the literature). Also, the I-880 data show a much higher proportion of accidents occupying two or more travel lanes.

On average, there was 0.5 incident per directional freeway kilometer (0.80 incident per directional freeway mile) per hour of data-collection shift, which translates into an average time interval of 6.1 hr between incidents occurring within a 1-km freeway segment. The number of incidents was approximately the same for each direction of the study section.

The variation in the number of observed incidents per data-collection period was due to time of day, day of the week, type of vehicle or vehicles involved, and weather conditions. More incidents

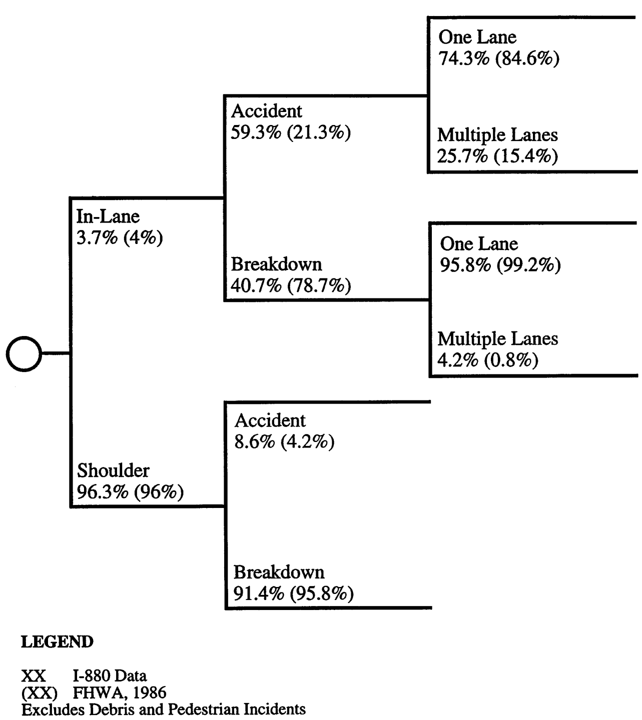

FIGURE 1 I-880 incident tree.

were observed during the p.m. peak than during the a.m. peak, particularly breakdowns on the right shoulder, which is attributable to the higher volumes in the p.m. peak. Also, more incidents were observed on Mondays and Fridays than on the rest of the weekdays.

The distributions of incident occurrence for all the incidents and per incident type were tested against statistical distributions. The Poisson distribution provided an adequate fit for the incident frequency, suggesting that the number of incidents in any period is random and independent of the number of incidents in any other time interval. The form of the Poisson distribution is

$$P(n) = [\exp(-m)m^n]/n! \qquad (1)$$

where $P(n)$ is the probability of having n incidents per shift and m is the Poisson parameter. Figure 2 graphs the fit of the Poisson distribution to the observed number of breakdowns in each data-collection shift.

Accidents accounted for 10 percent of the total incidents. On average, there were 3.8 accidents per 6-hr peak period, considerably higher than the accident frequency observed elsewhere—3.1 accidents per 24-hr day on a section of the Interstate 10 (I-10) freeway in Los Angeles (*7*). Table 2 indicates that most were noninjury accidents and that about 49 percent of all accidents involved more than two vehicles. In-lane accidents accounted for 21.4 percent of all accidents. Weather conditions had a significant effect on the accident frequency. The average accident frequency on rainy days doubled (3.5 accidents per shift during rainy shifts versus 1.5 accidents per shift during clear weather). Also, there was a higher frequency of accidents on segments with weaving areas and lane drops.

Response and Clearance Times of Assisted Incidents

The incident response times were calculated as the difference between the time the incident was first witnessed and the tow-truck arrival time. For the incidents involving CHP officers, the response time was calculated as the difference between the time the incident was first witnessed and the arrival time of the first CHP unit. The clearance time was calculated as the difference between the tow-truck or CHP-unit arrival time and the time it left the incident scene. Response and clearance times could not be calculated for those incidents that were in progress at the beginning or the end of the data-collection periods and for those incidents that were observed at the beginning of the period but were not removed by the end (mostly abandoned vehicles).

The response times per incident type and location are given in Table 3. The table also gives separately the response times of the FSP tow trucks in the after study. The number of assisted accidents was approximately the same, but the number of assisted breakdowns increased by 120 percent in the after study, largely because FSPs assisted all stranded motorists encountered during their patrol of the beat. In the before study, tow trucks were called by the motorists or CHP when assistance was needed. Most of the non-FSP assists in the after study involved accidents with CHP response.

The average response time for all incidents was reduced by 36 percent in the after study. This was due to the faster response times of FSPs to assisted breakdowns (the average response time for those incidents was reduced by 57 percent). Also, the larger sample of assisted incidents contributed to the response-time reduction. The FSP assists represent 77 percent of the total assisted incidents in

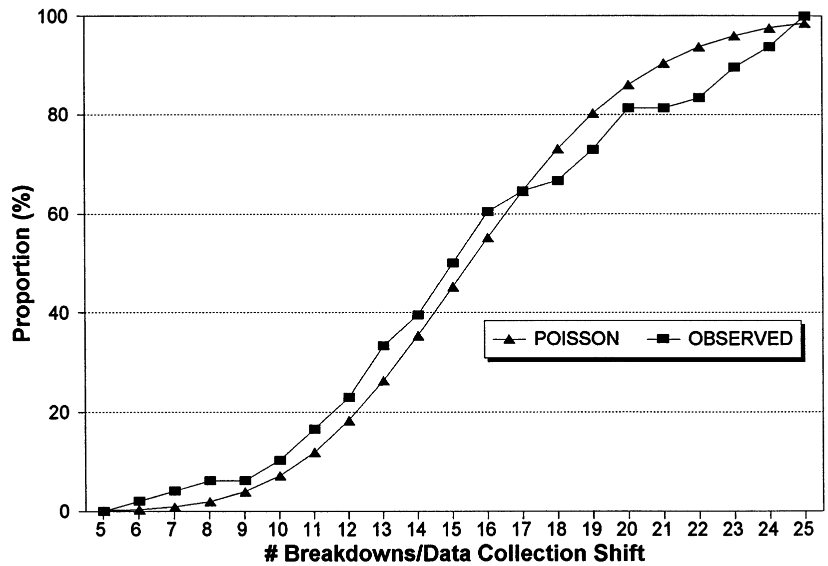

FIGURE 2 Distribution of incident frequency.

the after study, twice the number of assisted incidents in the before study. Eighty percent of the breakdowns in the after study had response times of less than 20 min, as opposed to 40 percent in the before study.

The average response times for accidents before and after FSP implementation were approximately the same, despite the faster response times of the FSPs (Table 3). This reduction, however, is not reflected in all the assisted accidents because of the small sample size and the large response time for five major accidents in the after study (most of those accidents involved multiple tow trucks with an average response time of 44 min).

The average clearance time for all assisted incidents was about 9 min. The average clearance time for breakdowns on the shoulder was 7 min, indicating that most of those incidents were minor stalls. Accidents and lane-blocking incidents took about 20 min on average to clear. The differences in the clearance times before and after FSP implementation were not statistically significant for the accidents or breakdowns and type of assist.

Incident Durations

Incident duration was calculated as the difference between the first time and the last time the incident was witnessed by the probe-vehicle drivers. Figure 3 presents the patterns of incident durations per incident type and type of assist. Sixty-five percent of observed breakdowns and about 35 percent of accidents were witnessed only

TABLE 2 Accident Severity Characteristics

INJURIES			VEHICLES INVOLVED			LANES CLOSED		
N	#Accidents	(%)	N	#Accidents	(%)	N	#Accidents	(%)
0	150	90	1	12	7.2	0	132	79
1+	17	10	2	73	43.7	1	26	15.6
			3	50	29.9	2+	9	5.4
			4+	32	19.2			

once and thus have zero duration according to the definition used for calculating duration from the field logs. The true mean duration of such incidents does not exceed the average headway of probe vehicles (7 min). The average duration of the rest of the incidents with observed start and end times was 25 min.

Figure 3 illustrates the patterns of incident durations for accidents and breakdowns. The mean duration of assisted breakdowns was reduced significantly in the after study because of faster FSP response time, which was cut from 37.6 min before to 21.1 min after the implementation of FSPs (a reduction of 35 percent). There was no significant difference in the accident durations despite the reduction in duration of FSP assists (41.2 min before versus 28.6 min after). However, as previously mentioned, the small sample size of observed accidents and the long durations of a few major accidents reduce the level of improvement for all incidents. As expected, there was no difference in the average durations for the nonassisted incidents or for incidents assisted by non-FSP tow trucks.

The typical values and distributions of all the incidents were essentially the same (Figure 4). A Kolmogorov-Smirnov (K-S) statistical found that the durations of all the incidents after implementation of FSPs have the same distribution as before, despite the significant reductions in response times by FSPs and the increase in the fraction of assisted incidents by 120 percent. This implies that FSPs assist predominantly minor incidents, that is, the K-S statistical oversamples the incidents of short duration.

The fractions of assisted incidents in each study period are presented in Figure 5 as a function of incident duration. The fractions of assisted incidents are considerably higher for the short-duration incidents in the after study. The reduction in duration of these incidents (mostly minor disablements) does not change the typical values or the distributions of durations for all the incidents in the study section.

COMPARISON OF FIELD AND CHP/CAD DATA

Following such a comprehensive field data-collection effort, the question arises whether the existing data sources such as the CHP/CAD incident logs can provide information rich enough for

TABLE 3 Average Response Times in Minutes—Assisted Incidents

INCIDENT TYPE/ LOCATION	BEFORE		AFTER				% CHANGE	
			ALL		*FSP*			
	N	Response	N	Response	N	Response	*ALL*	*FSP*
Accident	17	20.8	19	20.1	14	11.5	3.4	44.7
Breakdown	33	33.0	77	18.0	60	14.3	45.5*	56.7*
In-Lane	5	34.8	8	29.5	4	14.3	15.2	58.9
Right Shoulder	36	28.2	73	16.7	57	12.3	40.8*	56.4*
Left Shoulder	9	28.6	15	20.5	13	20.2	28.3	29.4
All	50	28.9	96	18.4	74	13.8	36.3*	52.2*

*: *Differences statistically significant at 5 percent level*

incident characterizations to be drawn. It is recognized that the CAD logs do not include tow-truck arrival and departure times for non-FSP trucks (before-study conditions) unless there is CHP activity and rotational tow-company data are available. However, the correlation of both the field observations and CAD data revealed that the readily available incident durations from the CAD logs have the same distribution and average duration as the field data from probe vehicles on the study section.

During this analysis, focus was placed on incidents that cause congestion delay and are of primary interest in incident management. The effect of incidents on traffic flow was determined by plotting the incident location on speed and density contour plots for the freeway

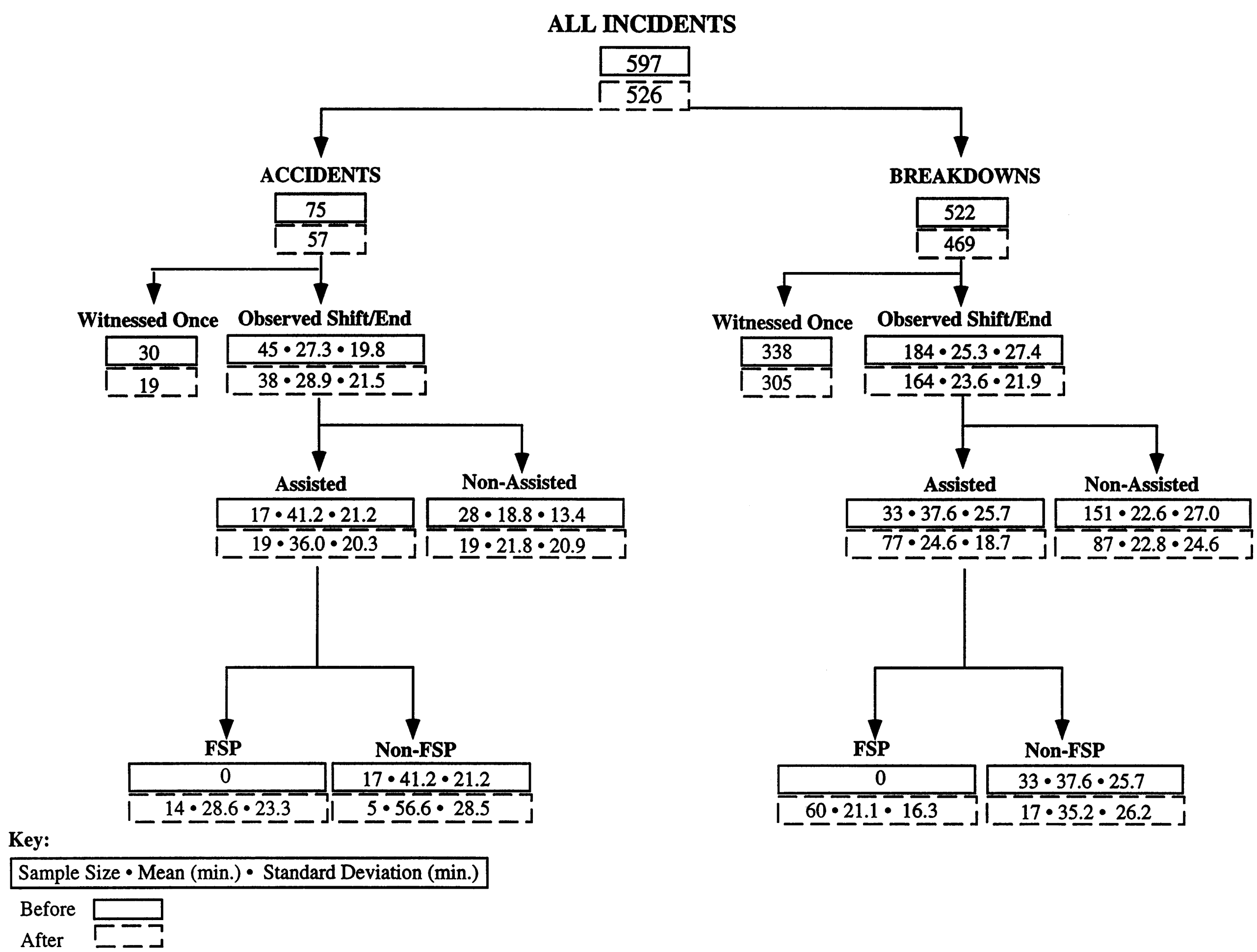

FIGURE 3 Incident duration patterns.

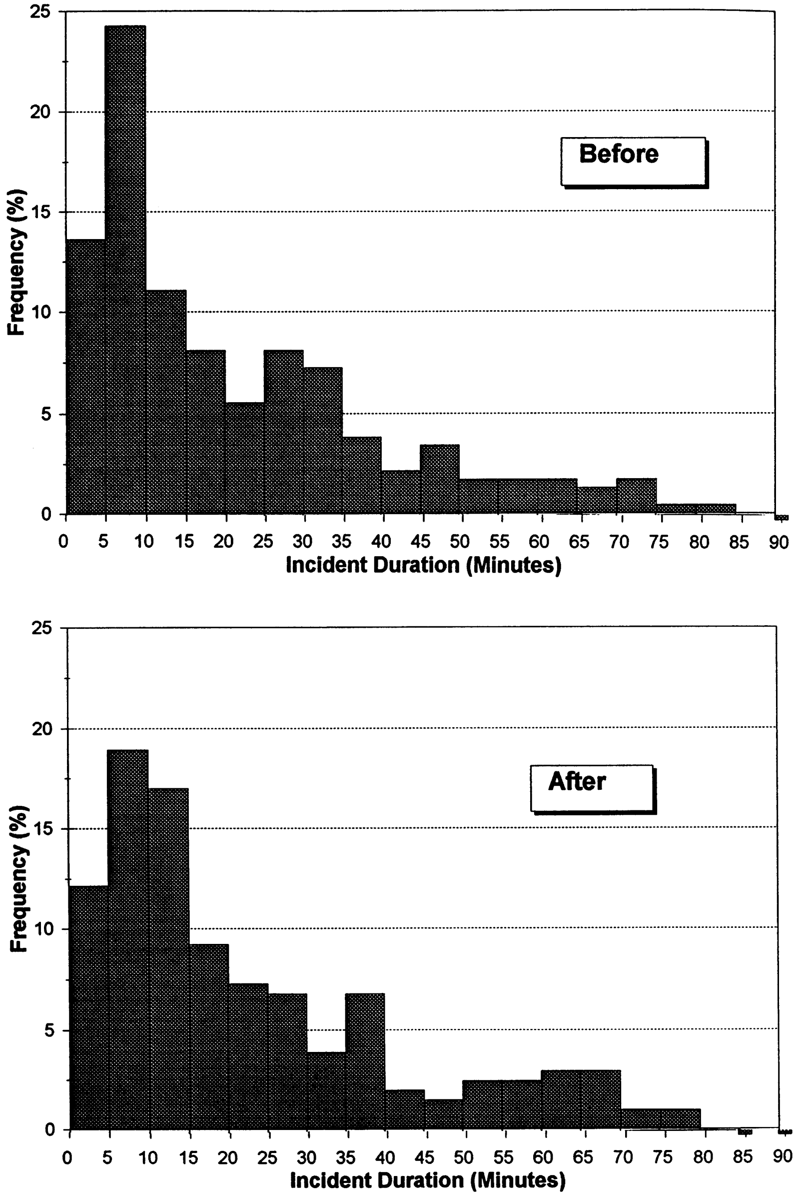

FIGURE 4 Distributions of incident durations.

section derived from the loop-detector data and calculating the delay as the difference in travel times under normal and incident conditions (*10*). A total of 109 delay-causing incidents were identified in the after study (Data set 1).

An attempt then was made to determine whether these field-recorded incidents were reported in the CAD system. A total of 56 incidents (Data set 2) or 51 percent was matched with incidents contained in the CAD database. Approximately the same percentage was found for the before study. The statistics and cumulative distributions of incident durations for the two data sets are illustrated in Figure 6. The 56 incidents in the CAD data base were found to be a representative sample of duration of the 109 probe-reported incidents. The results of this analysis indicate that CAD data may be used to determine typical values and distributions of duration for the delay-causing incidents in the freeway section.

CONCLUSIONS

A substantial number of incidents were observed at the study section. The average frequency was 47 incidents per day during the peak periods, and the estimated incident rate was about 64.6 incidents per million vehicle kilometers (100 incidents per million vehicle miles) of travel. There were about 0.5 incident per directional freeway kilometer (0.8 incident per directional freeway mile) per hour on the study section. Most of the incidents were vehicle breakdowns on the shoulders. Approximately 10 percent of all incidents were accidents, and 4 percent of all incidents were blocking travel lanes. Time of day, day of the week, presence of shoulders, traffic volumes, and weather conditions accounted for most of the variability in the incident occurrence. The Poisson distribution provided an adequate fit for the observed frequency distribution of breakdowns per data collection shift.

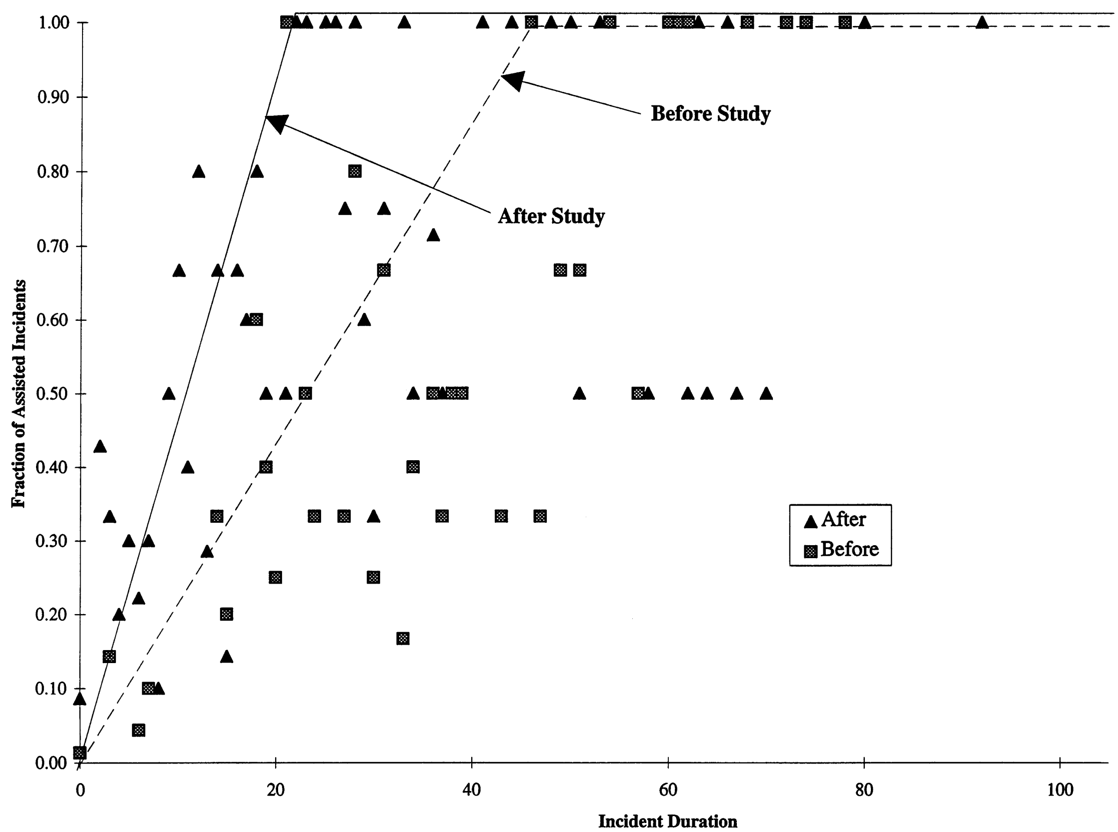

FIGURE 5 Distribution of fractions of assisted incidents.

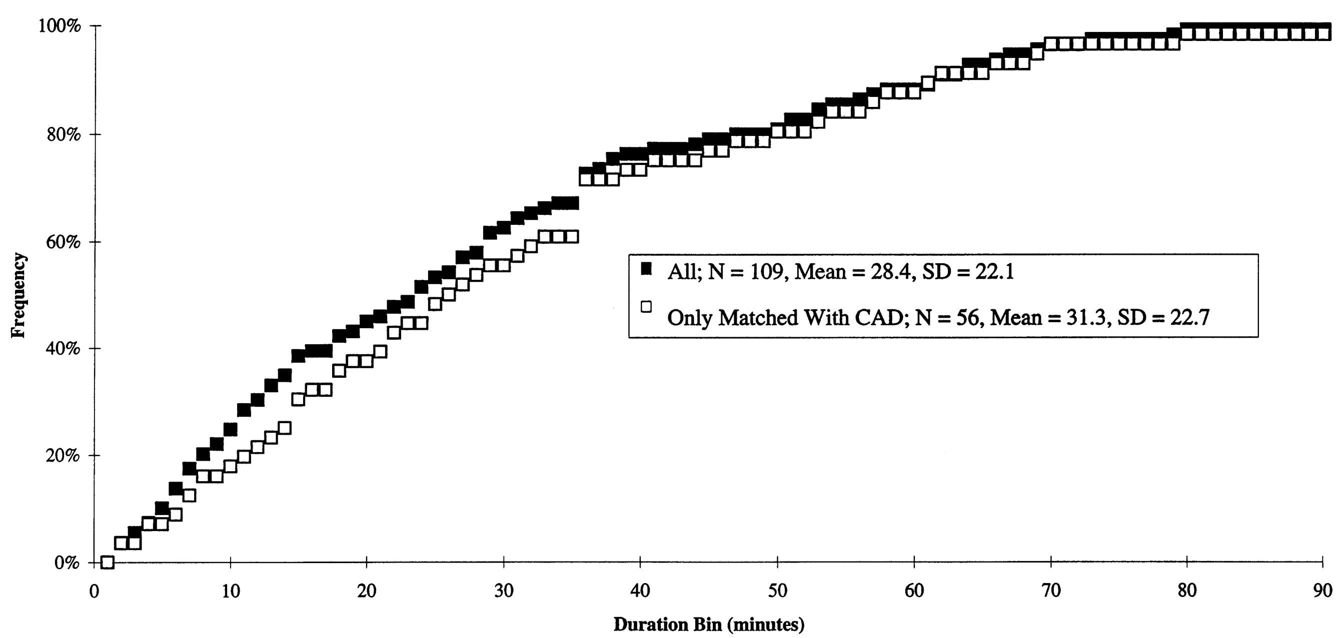

FIGURE 6 Distribution of durations for delay-causing incidents.

Incident response, clearance times, and durations depend on the incident type and severity and the availability of incident management measures. The average response time was 29 min in the before study and was reduced to 18 min after the implementation of FSPs. The average clearance time of incidents and lane-blocking accidents was 20 min. Breakdowns on the shoulder took 7 min on average to clear. The average duration of all incidents was 25 min with 85 percent of the incidents lasting up to 50 min.

Implementation of FSPs at the study section in the after study significantly reduced the response time of assisted breakdowns, by 57 percent. The proportion of tow-truck-assisted incidents was increased by 120 percent. However, implementation of FSPs did not result in a significant change in the overall pattern of incident characteristics before and after implementation because FSPs predominantly assist minor incidents; thus incidents of short duration were oversampled.

Comparisons of the distributions of durations from field measurements and the CHP/CAD logs indicate that incident durations from the CAD system are a representative sample of the durations of delay-causing incidents; which is the primary interest in incident management.

There is a need for additional comprehensive data collection and analysis efforts on other sites to determine incident patterns and their effect on freeway traffic flow for a range of operating conditions. Such an effort is in progress at a Los Angeles freeway site (*13*). These data bases could be used to update the typical values on incident frequency and characteristics used in many studies, formulate improved guidelines for deployment and evaluation of incident management programs, and develop and calibrate improved incident-detection algorithms and simulation models.

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